Appendix C
Infested Lake Control Strategies

The information included in this Appendix was provided by Kathy Hamel of Ecology's Aquatic Weed Program. This information is also available through the following website: http://www.ecy.wa.gov/programs/wq/plants/management/aqua026.html

PHYSICAL/MECHANICAL METHODS ....

MECHANICAL HARVESTING

Harvesting is a way to mechanically remove milfoil in order to provide open areas of water for recreational activities and navigation. Harvesting immediately removes surfacing milfoil mats, but since the cut plants grow back (sometimes within weeks), the same area may need to be harvested twice or more per growing season. Harvesters are specialized underwater mowing machines specifically designed to cut and collect aquatic plants. Cut plants are immediately removed from the water via a conveyer belt. The cut plants are stored on the machine until they can be off-loaded and disposed of properly. Several manufacturers sell various sizes and models of machine, and there are firms that contract for harvesting operations. More information about harvesting is available at the following web address:

Waterbodies suitable for harvesting programs:
Waterbodies suitable for harvesting programs include larger lakes (about 100 acres or more), and rivers with widespread, well-established milfoil populations, where milfoil eradication is not an option. Harvesting operations are on-going and expensive. It is important that a large lake association, residential community, or a motivated local government is willing to share the harvesting costs.

Special considerations:
Harvesting is not recommended in waterbodies with early infestations of milfoil since the resulting fragments are never completely contained and harvesting may increase the spread of milfoil throughout the waterbody. Because harvesting is a whole-lake activity it should be conducted under the direction of an integrated aquatic vegetation management lake plan. Factors to consider when designing a harvesting program include:

- Lake surface area, width, and depth;
- Vegetated acres;
- Bottom contours and bottom obstructions such as stumps, rocks, other debris;
- Traffic patterns,
- Prevailing winds;
- Harvester launching and off-loading sites;
- Shoreline development; and
- Sensitive areas (critical habitat).

A reliable funding source, such as a Lake Management District or a committed local government, is necessary to provide funding either to purchase and operate a harvester or to contract for harvesting on an annual basis. In at least one jurisdiction (Skagit County, Washington), the County trained volunteers to operate the County-owned harvester to remove milfoil on local lakes. However, liability may become an issue with volunteers using harvesters since harvesting machines have been known to capsize when improperly filled or overloaded.

A lake committee and/or local government staff identifies acreages and areas to be harvested within the lake. Priorities may be determined by who funds the program. For example, a local government will be more interested in harvesting public areas, whereas the lake group may be interested in harvesting the areas in front their homes. In general, high use areas such as public parks, community access points, navigation channels, public boat launches, and water ski lanes receive priority for clearing. Because harvesters are large machines and are difficult to maneuver near-shore between and around docks, in at least one harvesting program (Long Lake, Thurston County) harvesting was limited to areas outside of the docks. Individual homeowners, at their discretion, were considered responsible for removing plants growing between the end of the dock and their shoreline.

Prior to harvesting, machinery launch sites (a paved ramp with deep water is best), and plant disposal off-loading sites need to be identified. A summer harvesting schedule must be developed. If harvesting services are contracted, bid documents and a contract need to be prepared.

Description of a harvesting project:
Harvesting starts when plants have neared or approached the water surface. The harvester's cutting head is lowered into the water and the harvester moves forward, cutting and collecting plants as it advances. Harvesters vary in size and capability. Most cut plants about five feet below the water and in a swath between five and ten feet wide. Bigger, faster machines with larger cutting heads and holding capacities may be more efficient, but are also less maneuverable. Depending on time of year, weather, and depth of cut, the same area may need to be harvested again in a few weeks.

The cuttings are collected on a conveyer belt and deposited in a holding area on board. Although the harvester collects most plant materials as it operates, inevitably some fragments are missed. Not overloading the carrying capacity of the harvester helps to keep plant fragments to a minimum. Along with plants, the harvester also inadvertently collects small fish (some are able to escape from the conveyer belt) and invertebrates.

When the plant storage area is filled, the harvester must off-load the cut plants. Plants can be off-loaded to either a barge stationed offshore or to a trailer or dump truck. These plants may be used as compost or disposed of in a land fill. As the distance from the work area to the off-loading site increases, the time spent on plant disposal activities can exceed the time spent cutting. This can add greatly to the duration and expense of the project and is a critical limitation to some harvesting projects. The plant density and machine specifications will also determine how often the harvester needs to off-load the cut plants.

Delays in the harvesting schedule can result from high winds, thunderstorms, and mechanical failure. Unscheduled maintenance or machine breakdowns can also result in lost harvesting time.

Complaints about harvesting have included reports by homeowners that plant fragments wash up more frequently on their beaches after harvesting. Homeowners may also report that their neighbor's property was harvested sooner or the job done more thoroughly than at their own property. It is important to establish some clear guidelines and policies to help make decisions and to settle disputes.

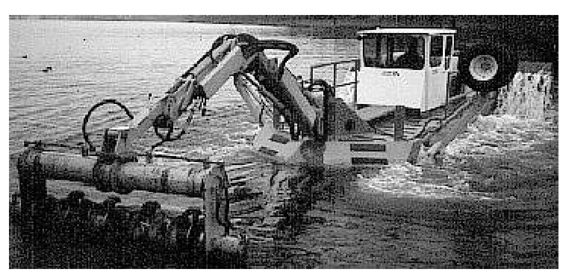
General impacts of harvesting:
While some people view harvesting as an excellent non-chemical control method for milfoil, others scoff at the waste of money to "merely mow the weeds." Harvesting plants has the added benefit of removing nutrients from the waterbody that are tied up in the plant biomass. Because only the top part of the plant is removed, the rest of the plants remain for habitat and sediment stabilization.

Harvesters are large machines and occasionally hydraulic fluid or fuel can be leaked or spilled. The operator should have a spill plan and containment equipment available at all times. When working in shallow water, the propulsion system or the cutter head can sometimes churn up the sediment creating turbid water. Significant numbers of fish can be removed from a waterbody during harvesting activities as fish become collected along with the cut plants (Mikol, 1985). These are often juvenile fish, because larger fish can more easily avoid the harvester. Long term milfoil harvesting programs in Washington state include; the Columbia River, Lake Washington, and Green Lake. There is also a program aimed at native plant control on Long Lake (Thurston County).

References:
Mikol, G. F. 1985. *Effects of harvesting on aquatic vegetation and juvenile fish populations at Saratoga Lake, New York*. Journal of Aquatic Plant Management. 23: 59-63.

Your Aquatic Plant Harvesting Program: A How-To Field Manual. Produced by the Wisconsin Lakes Partnership- University of Wisconsin-Extension, Wisconsin Association of Lakes, and Wisconsin Department of Natural Resources. Publication FH-205-97

ROTOVATION (UNDERWATER ROTOTILLING)



A rotovator is a barge-mounted rototilling machine that lowers a tiller head about eight to ten inches into the sediment to dislodge milfoil root crowns. The mechanical agitation produced by the tiller blades dislodges the root crowns from the sediment and the buoyant root masses float to the water surface. Since the entire plant is removed, plant biomass remains reduced in the treatment area throughout the growing season and often longer. Rotovation often provides two full seasons of control (Gibbons et. al, 1987). Unlike harvesters, rotovators do not have the capability to collect the plants. More information about rotovation is available at the following web address: http://www.ecy.wa.gov/programs/wq/plants/management/aqua027.html

Waterbodies suitable for rotovation programs:
Rotovation is a way to mechanically remove milfoil to provide open areas of water for recreational activities and navigation. Waterbodies suitable for rotovation include larger lakes or rivers with widespread, well-established milfoil populations where milfoil eradication is not an option. Since on-going rotovation programs are very expensive, having a large lake population or a motivated local government to share these costs is crucial. Because rotovation is expensive and multiple permits are needed, rotovation has not become a wide-spread milfoil control activity in Washington or elsewhere in the United States.

Special considerations:
Rotovation is not recommended in waterbodies with early infestations of milfoil since fragments are created and rotovation may increase the spread of milfoil throughout the waterbody. Because rotovation creates turbidity, rotovation may not be appropriate in salmon-bearing waters, although sometimes Fish and Wildlife staff are able to provide windows of time when rotovation activities will have the least impact on fish. Because rotovation and the resultant turbidity may impact the entire waterbody, it should be conducted under the direction of an integrated aquatic vegetation management plan.

Factors to consider when designing a rotovation program include:

- Waterbody surface area, width, and depth;
- Vegetated acres;
- Bottom contours and bottom obstructions such as stumps, rocks, other debris;
- Traffic patterns,
- Prevailing winds;
- Rotovator launching and off-loading sites;
- Sediment type;
- Shoreline development; and
- Sensitive areas (critical habitat).

A waterbody committee and/or local government staff identifies acreages and areas to be rotovated. Priorities may be determined by who funds the program. A local government will be more interested in rotovating public areas, whereas local residents may be interested in rotovating areas in front their homes. However, generally high use areas such as public parks, community access points, navigation channels, public boat launches, and water ski lanes receive priority. Sometimes rotovators can be used to create fishing lanes in dense beds of milfoil to provide better fishing access to anglers.

Prior to rotovation, machinery launch sites (a paved ramp with deep water is best) need to be identified. Since rotovators do not collect plants as they work, a method for removing plants from the water should be developed. This may involve having a harvesting machine follow behind the rotovator to collect plants or hiring people to rake plants off beaches. When Pend Oreille County rotovates milfoil in the Pend Oreille River, they begin at the milfoil bed furthest upstream. The plants are then carried downstream and get caught up on the remaining dense milfoil beds. Their rotovator also has a clam rake attachment that can be used to pick up the plants and place them on-shore. This removal technique is acceptable on the Pend Oreille because there are many uninhabited shoreline areas. This would not be suitable in well-populated bodies of water.

Description of a rotovation project:

During a rotovation project, the rotovator tilling head is lowered into the sediment and power is applied. The rotating head churns into the sediment dislodging milfoil root crowns and plants, and a plume of sediments. The rotovated plants eventually sink or wash up on shore and the sediments gradually settle from the water. Canadian plant managers have recorded milfoil stem density and root crown reductions of better than 99 percent after rotovation test trials (British Columbia Ministry of Environment memo dated 1991). Where repeated treatments have occurred at the same site over several consecutive years, treatment intervals may extend longer than two years (Gibbons, et. al, 1987).

If rotovation services are contracted, bid documents and a contract need to be prepared, but there are few, if any, contractors offering these services. In a few waterbodies such as in the Pend Oreille River, rotovation may be performed year-round. In most waterbodies, timing is dependent on fish windows. Washington Fish and Wildlife does not want rotovation activities to take place when fish are spawning or juvenile salmon are migrating through the waterbody.

For efficacy of milfoil removal, it's best to begin operations in early spring and resume again in the fall. Rotovation is less effective in the summer when the long milfoil plants wrap around the rotovating head, slowing down the operation. If rotovation is done during the summer, it is more efficient to cut or harvest the plants beforehand. Weather creates winter rotovation delays, although it is possible to rotovate throughout the winter months (as long as the waterbody doesn't freeze). Delays in the rotovation schedule can result from high winds, thunderstorms, freezing water, and mechanical failure. There is a lot of maintenance and some down time on machinery working on the water.

Complaints about rotovation include increased plant fragments washing up along shorelines, broken water intakes, and homeowners perceiving that their neighbor's property was rotovated sooner or more thoroughly than their own property. It is important to establish some clear guidelines and policies to help make decisions and to settle disputes.

General impacts of rotovation:

Rotovators stir sediments into the water column. In addition to the sediments, buried toxic materials and/or nutrients may be released. Generally turbidity is short-term and the water returns to normal within 24 hours, but the length of time that sediments remain suspended depends on sediment type. Plants and root crowns are uprooted from the sediment and unless a plant removal plan is in place, these plants will either sink or be washed on shore. Rotovation appears to stimulate the growth of native aquatic plants. Whether this is due to the removal of milfoil, the action of the rotovator stimulating seed or propagule germination, or a combination of these factors is not known. Rotovators are also large machines with hydraulic systems and fuel that occasionally leaks or is spilled. The operator should have a spill plan and containment equipment on board for emergency use.

In 1987, Ecology conducted an evaluation of rotovation in Lake Osoyoos. This lake was chosen because it has a history of mining and agricultural use and therefore might represent a "worst case” scenario in terms of the potential for release of contaminants from sediment. The objectives of the study were to document effectiveness of rotovation by measuring changes in milfoil stem densities before and after treatment, and to assess impacts of rotovation on selected water quality parameters, benthic invertebrates, and the fisheries. Although the rotovator malfunctioned during the test (the hydraulic system driving the rototiller was not functioning properly), the results were consistent with data collected by the British Columbia Ministry of the Environment of sites rotovated by a fully operating rotovator. During the Lake Osoyoos rotovator test, rotovation appeared to have little impact on fish, water quality, or benthic invertebrates. However during this test, milfoil stem densities were not reduced to the extent that should have occurred had the machinery been operating properly. Although the results indicated only short-term impacts associated with rotovation, the test was faulty and it is difficult to draw firm conclusions. This study was not repeated using a fully functioning machine

References:
Gibbons, M.V., Gibbons, H.L., and Pine, R.E. 1987. *An evaluation of a floating mechanical rototiller for Eurasian watermilfoil control*. Department of Ecology. Publication Number 87-17.

DIVER DREDGING

Diver dredging is a mechanical control technology for milfoil removal that was pioneered by the British Columbia Ministry of Environment. During diver dredging operations, divers use venturi pump systems (small gold mining dredges) to suction plants and roots from the sediment. The pumps are mounted on barges or pontoon boats and the diver uses a long hose with a cutter head to remove the plants. The plants are vacuumed through the hose to the support vessel where the plants are retained in a basket and sediment and water are discharged to the waterbody. Often a silt curtain is deployed around the treatment site to control turbidity. To learn more about diver dredging, see the following web page:
http://www.ecy.wa.gov/programs/wq/plants/management/dredging.html

Waterbodies suitable for diver dredging:
Sites suitable for diver dredging include lakes or ponds lightly to moderately infested with milfoil. Because diver dredging can be very expensive, this method is most suitable for moderate to early infestations of milfoil and for follow-up milfoil removal after an herbicide treatment. Diver hand pulling is more effective in lightly scattered patches of milfoil, whereas diver dredging may be more appropriate in denser milfoil beds. Diver dredging may also be applicable in waterbodies where no herbicide use can be tolerated. Theoretically diver dredging could be used in any waterbody to eradicate milfoil; however the costs for large scale projects would become astronomical.

Special Considerations:
Development of an integrated vegetation management plan is advised prior to beginning a diver dredging project. Diver dredging projects may require a federal permit from the US Army Corps of Engineers. The necessity for this permit is site dependent.

Description of a diver dredging project in Washington:
The littoral zone of the lake is surveyed immediately prior to starting control work and milfoil locations are mapped and Global Positioning System (GPS) points established.
Diver dredging can begin as soon as milfoil can be easily seen and identified - generally in the spring. If diver dredging is being used as a milfoil eradication method also see the milfoil eradication strategy using hand pulling and bottom barrier installation. Diver dredging can be used in conjunction with these other methods to achieve eradication; with dredging used to reduce the density of plants, followed up by hand pulling. Generally diver dredging projects continue for several years and are very expensive.

During diver dredging, the divers may use a tool to loosen milfoil root crowns before using a suction head to remove the plant. In hard-packed or rocky sediments, the plants often break off at the root crown, leaving the root behind to regrow. In these areas, alternative control methods, such as bottom barrier installation, should be used. In locations with denser milfoil colonies, divers should make several passes through the area to ensure that all plants have been located and removed. Removed plants can be used for compost rather than having to be discarded as solid waste.

Factors that affect the success of diver dredging include: sediment type, visibility, amount of fragments created, density of native aquatic plants, and effort expended. The amount of acres covered per day is dependent on plant density, ease of removal, and number of divers. Once milfoil plants have become sparse, diver hand pulling is just as fast as dredging and has less impacts.

Sometimes diver dredging equipment is used just to transport plants to the surface. The diver pulls the plant and uses the dredge hose to suction the plant to the support boat rather than placing the plants in a bag and carrying them to the surface. Using a dredge for plant disposal is not considered dredging and does not trigger the need for Corps of Engineers approval.

In Washington, diver dredging was used in Silver Lake in Everett to contain a relatively early infestation of milfoil. Although milfoil was not eradicated in Silver Lake, dredging, in combination with hand pulling and bottom barrier installation, did remove most of the milfoil from the lake. Diver dredging is also being used in Idaho lakes and rivers to contain recently discovered milfoil populations.

General impacts of diver dredging:
No research has been conducted in Washington to quantify the impacts of diver dredging. Although the object of diver dredging is to remove milfoil, sediment is unavoidably stirred into the water. The obvious impact of diver dredging is increased turbidity in the area of plant removal with the degree of turbidity dependent on the sediment type. Fine silty sediments produce more turbidity than sandy or rocky sediments. If turbidity interferes with the ability of the divers to see the milfoil plants, efficacy of plant removal can be affected. Diver dredging may also release buried pollutants and/or nutrients. In Silver Lake, sediment bioassays were required prior to dredging to ensure that the sediments did not contain toxic materials. Bioassays are probably more important in waterbodies with a history of mining, combined sewage outfalls, land filling, storm water outfalls, or other activities that may have contributed pollutants to the sediments.

It is very difficult to control fragment release during dredging operations. If a silt barrier is deployed around the dredging site for turbidity control, divers should make an attempt to collect milfoil fragments within the area before removing the barrier.

Follow-up to treatment:
Diver dredging, used alone, is probably not an eradication tool, but it can be the first step to reducing the biomass of milfoil to the point where other manual methods can be used to eventually eradicate the plant.

WATER LEVEL DRAWDOWN

Milfoil can sometimes effectively be controlled when waterbodies are dewatered by releasing water via a water level control structure (dam or weir) or by pumping. The effectiveness of milfoil control is determined by several factors including the amount of the waterbody bottom exposed, duration of exposure, presence of springs, and the weather at the time of drawdown. The success or failure of drawdowns in controlling milfoil can be highly variable from lake to lake and from year to year within the same waterbody (Vermont Agency of Natural Resources, 1989). Cook (1984) recommended lake level drawdown for macrophyte control in situations where prolonged (one month or more) dewatering of lake sediments is possible under rigorous conditions of cold or heat; a key factor is desiccation. The author pointed out that those conditions suitable for macrophyte control may not occur with heavy snowfall or during milder, rainy winters. More information about water level drawdown is available at the following web address: http://www.ecy.wa.gov/programs/wq/plants/management/drawdown.html.

Waterbodies suitable for water level drawdown:
In Washington, milfoil control has usually been a side benefit of drawdown regimes occurring in waterbodies and reservoirs for other purposes such as for power generation, irrigation, or flood control. The impacts of fluctuating water levels are severe on a natural waterbody, so this activity rarely occurs <u>solely</u> for milfoil control in Washington. Waterbodies suitable for water level drawdown are those with infestations of milfoil where drawdown occurs on a prolonged and regular basis. Because western Washington is so much wetter and milder than eastern Washington, drawdown is generally more successful in controlling eastern Washington milfoil populations. However, in some western Washington reservoirs, such as Tapps Lake and Riffe Lake, prolonged annual drawdowns have helped control milfoil infestations. Since milfoil survives in deeper water, drawdowns will not eradicate milfoil from the waterbody. Generally waterbodies with fluctuating water levels such as reservoirs are highly perturbed systems.

Special considerations:
Because water level drawdown impacts the entire waterbody, it should be conducted only under the direction of an integrated aquatic vegetation management plan. Few waterbodies in Washington, except for reservoirs, have water control structures and the means to lower the water level to the extent necessary to achieve significant milfoil control. Some lakes with water level controls also have court adjudicated water levels. Because impacts to habitat are severe, drawdown should only be considered as a milfoil control in waterbodies where the habitat value is not considered important by resource agencies.

Factors to consider when evaluating water level drawdown as a possible control for milfoil include:

- Presence of an outlet structure or the means to lower the water level;
- Amount of waterbody bottom exposed at different water levels;
- Timing of water withdrawal and return;
- Climate;
- Potential impacts to surrounding wetlands/emergent plants;
- Sediment type;
- Shoreline development;
- Species dependent on near-shore habitat;
- Endangered species and/or rare plants; and
- Sensitive areas (critical habitat).

General impacts of water level drawdown:
As the water recedes, docks and other shoreline structures, such as retaining walls and irrigation or potable water intakes, are exposed and shallow wells may run dry. It may become impossible to launch boats, and boating and other recreational activities may be curtailed or restricted during drawn down periods. On the plus side, lowered water levels may allow repairs to be more easily made to near-shore structures. Sometime drawdown can consolidate flocculent sediments and results in firmed sediments when the water returns.

Water level drawdown exposes the sediment and affects the habitat for emergent and submersed plants, fish, benthic invertebrates, waterfowl, and aquatic mammals. Vermont concluded that drawdown did major damage to deepwater wetland communities at Lake Bomoseen. It caused decreases to two rare plant species and provided only short-term control of milfoil. Greening and Gerritsen (1987) noted that frequent drawdowns result in a reduction in species diversity and favor tolerant plants which eventually come to dominate the lake.

The impacts to animals by the Lake Bomoseen winter drawdown (September 1988 to March, 1989) were also significant. The drawdown "decreased habitat suitability for species that require stable water levels such as beaver and muskrat by preventing them from using their winter food supplies and exposing them to adverse weather and predation. Habitat suitability was decreased for species that overwinter in the bottom sediments such as frogs, turtles, and macroinvertebrates because freezing the sediment kills these animals." The Vermont report also concluded that the drawdown of Lake Bomoseen had an adverse impact on all the littoral zone macroinvertebrate communities (snails, mussels, aquatic insects). The impacts to fish by the Lake Bomoseen drawdown were difficult to measure because only one year of data was collected.

Other impacts that may occur after drawdown include:

- Low lake levels after winter drawdowns if insufficient spring rains fail to refill the waterbody;
- Dried up streams as water flows from the lake cease;
- Damage to the lake bottom; and
- Nutrient releases and algal blooms that occur after the water level rises.

There is some anecdotal evidence in Washington to suggest that milfoil seeds may germinate after summer lake bottom desiccation. In two small natural lakes in Thurston County where milfoil had been eradicated, milfoil appeared in abundance after drought conditions contributed to partial or whole lake drawdown. The fall/winter following the drought, the lakes refilled and an abundant population of milfoil was observed in the spring/summer, particularly in the areas where the lakes had been dewatered.

References:

Cook, G. D. 1984. *Lake level drawdown as a macrophyte control technique.* Water Resources Bulletin, Vol. 16, No. 2.

Greening, H.S. and Gerritsen, J. 1987. Changes in macrophyte community structure following drought in the Okefenokee Swamp, Georgia. USA. Aquatic Botany, 28:113-128.

A report prepared for the Vermont Legislature by the Vermont Agency of Natural Resources, Waterbury, Vermont. 1989. *The Lake Bomoseen drawdown: An Evaluation of its Effects on Aquatic plants, wildlife, fish, invertebrates, and recreational uses*.

HAND PULLING AND BOTTOM BARRIER INSTALLATION

During hand pulling, milfoil plants are manually removed from the lake bottom, with care taken to remove the entire root crown and to not create fragments. In deeper water, divers are usually needed to reach the plants. See this web page for more information about hand pulling techniques: http://www.ecy.wa.gov/programs/wq/plants/management/aqua022.html.

Bottom Barrier Installation:

Bottom barriers are semi-permanent materials that are laid over the top of milfoil beds and are analogous to using landscape fabric to suppress the growth of weeds in yards. To learn more about bottom barriers and their environmental impacts, see the following web page: http://www.ecy.wa.gov/programs/wq/plants/management/aqua023.html. To learn more about installing bottom barriers, see this site:
http://www.ecy.wa.gov/programs/wq/plants/management/aqua021.html

Waterbodies suitable for handpulling and installation of bottom barriers:

Due to expense and the time intensive nature of manual methods, sites suitable for hand pulling and bottom screening are limited to lakes or ponds only lightly infested with Eurasian watermilfoil. This method is suitable for very early infestations of milfoil and for follow-up removal after a whole lake fluridone treatment, a 2,4-D treatment, or diver dredging. To be cost-effective, generally the total amount of milfoil in the waterbody should be three-acres or less in total area. If the infestation has advanced beyond this point, it is more effective to consider other eradication techniques such as aquatic herbicides. This method may also be applicable in waterbodies where no herbicide use can be tolerated such as in a lake used as a municipal drinking water supply. Theoretically, these methods could be used in any waterbody to eradicate milfoil; however the costs for large scale projects would become astronomical.

Special Considerations:
Factors that affect the success of hand pulling include: water clarity, sediment type, suppression of milfoil fragments, density of native aquatic plants, and effort expended. It is especially important to have good visibility for the divers to locate milfoil plants. Sometimes diving is only effective in the spring or fall, or during periods between algal blooms. If water clarity is very poor, manual eradication methods may not be suitable for the waterbody.

Description of a milfoil eradication project in Washington using handpulling and bottom barriers:
Lakes where manual methods are being used for milfoil eradication typically have milfoil lightly scattered singly or in small patches within the littoral zone. To determine the extent of the infestation, the littoral zone of the lake is surveyed immediately prior to starting control work and milfoil locations are mapped and Global Positioning System (GPS) points established. The survey can be conducted prior to the removal effort or take place during the removal effort.

Hand pulling can begin as soon as milfoil can be easily seen and identified - generally in the spring or as soon as it is discovered in the lake. Despite milfoil's tendency to fragment more readily during the fall, removal should be undertaken as soon as possible after the discovery of milfoil in the lake, no matter how late in the season. Both surface and underwater surveys should be conducted several times during the growing season. During the surface survey, a surveyor moves slowly through the littoral zone in a boat, looking into the water (often using a viewing tube), and marking the locations of milfoil plants with buoys. The surface survey is immediately followed by an underwater diver survey. Because known milfoil locations have been marked during the surface surveys, the divers can concentrate their efforts at these locations. Since diver time is expensive, it can be cost-effective to conduct surface surveys before underwater surveys.

During hand pulling, the divers dig around and beneath the plant roots with their hands or with a tool and gently lift the entire plant out of the sediment. The ease of removal is dependent on sediment type. Milfoil plants can be readily removed from loose or flocculent sediments. In hard sediments or rocky substrate, hand tools must be used to loosen the root crown before the plant can be dislodged. Sometimes fine roots are left behind; these will not regrow, but it is important to remove the root crown (the fleshy, fibrous roots at the base of the stem). Once plants are removed, the diver places them into bags for transportation to the surface. Sometimes divers may use a suction device to deliver the plant to the surface. The plant is sucked up into the boat (generally using a gold dredge), the plants are retained in a sieve, and the water is discharged back into the lake. In locations with denser milfoil colonies, divers should make several passes through the area to ensure that all plants have been located and removed. As the divers work, the people in the support boat mark the locations of milfoil plants. An accurate location is important since the areas need to be resurveyed a few weeks later. There have been instances when small fragments or plants have been overlooked and have become large plants upon resurvey. Removed plants can be used for compost rather than having to be discarded as solid waste.

If colonies are too large for efficient hand pulling or if repeated visits to the same site indicate that too many fragments or plants are being missed, bottom barriers should be installed. Burlap bottom barrier (or other biodegradable material) should be placed over the plants and anchored to the lake bottom using natural materials such as rocks or sandbags. The burlap should cover and extend well beyond the growth zone of the plants. Burlap or other natural materials are preferred because they will naturally decompose over a 2-3 year period.

Some lake groups hire contract divers and surveyors to conduct manual plant removal activities. Other lakes have relied on volunteer efforts. If volunteers are used, they must be trained in plant identification and proper removal methods.

General Impacts of hand pulling
Special care must be taken to prevent the release of milfoil fragments. At certain times of the year (generally after flowering), milfoil plants can fracture into hundreds of fragments, each having the potential to form a new plant. To help contain the fragments, individual plants may be covered with a mesh bag before they are pulled. The driver of the diver support boat must also be careful not to create additional fragments by keeping the boat and propeller out of the milfoil plants. People in the support boat should use net skimmers to retrieve any fragments accidentally released by the divers.

Hand pulling may increase turbidity in the area of removal. This can affect the efficacy of removal if the turbidity interferes with the ability of the divers to see the milfoil plants.

Follow-up to treatment:
Follow-up is essential to ensure the success of eradication. Even a few milfoil fragments left in the lake can start a new infestation or boaters may reintroduce milfoil into the lake. Diver and surface inspections should continue at least twice a year during the growing season. Survey work should be as frequent as can be afforded since small milfoil plants or fragments may be easily overlooked.

Long term follow-up is the key!
Once milfoil is discovered in a lake, it generally requires continual maintenance to keep it at low levels. Even if milfoil appears to have been eradicated, it often is reintroduced by boaters. As long as the lake group continues surveying, new introductions can be identified quickly and targeted for removal before milfoil can reestablish in the lake. Although labor intensive, these manual techniques have been used to successfully eradicate milfoil in a drinking water reservoir in Washington.

OTHER HOMEOWNER CONTROL OPTIONS

In addition to handpulling and installation of bottom barriers there are varied other techniques that can be applied to a smaller control area. These are often applied by homeowners. They include:

- Cutting (using special cutting tools);
- Raking;
- Weed Rollers® (a device that consists of motor-driven metal cylinders that roll in an arc along the lake bottom);
- Diver dredging (a diver-operated suction dredge that vacuums milfoil from the lake bottom); and

- Spot treatment with herbicides (chemicals appropriate for killing or suppressing milfoil growth in small areas).

Waterbodies suitable for homeowner local control options:
Waterbodies suitable for individual home owner control options include lakes or ponds heavily infested with milfoil, where there has not been a comprehensive or lake-wide milfoil management plan developed and implemented. Or, where a plan has been developed and it calls for homeowner control. In these situations it is up to each homeowner, at their expense, discretion, and with proper permitting, to remove milfoil from their lake front property. Some of these methods may not be suitable in waterbodies experiencing an early infestation of milfoil because fragments may be created and cause increased spread.

Many of these methods offer only temporary relief because milfoil fragments will drift in from adjacent unmanaged areas and invade the cleared area. Some actions, for example cutting, raking, and handpulling, need to be repeated at intervals during the summer to maintain milfoil-free areas. Methods, such as installing bottom barriers (if kept maintained) or installing a weed roller (if operated on a regular basis), may offer longer term control. Spot treatment with aquatic herbicides may result in adjacent waters being inadvertently treated through drift. It is important to talk with neighbors to ensure that they are comfortable with the idea of chemical treatment before proceeding with any herbicide applications.

Description of methods:
All of these methods and their impacts have been described in detail on the Department of Ecology website. The web address for each method is listed below:

Manual Methods: http://www.ecy.wa.gov/programs/wq/plants/management/aqua022.html
- Hand pulling
- Cutting
- Raking

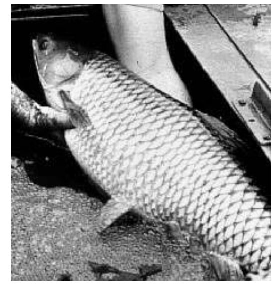
Weed Roller®:
http://www.ecy.wa.gov/programs/wq/plants/management/aqua029.html.

Diver Dredging:
http://www.ecy.wa.gov/programs/wq/plants/management/dredging.html.

Spot treatment with herbicides
http://www.ecy.wa.gov/programs/wq/plants/management/aqua028.html.

BIOLOGICAL CONTROL STRATEGIES ....

TRIPLOID GRASS CARP



Triploid grass carp are plant-eating fish from the Amur River Basin and lowland rivers in China and Russia. They are used as biological control for overabundant aquatic plants in some Washington waterbodies. Only sterile fish (triploids) are allowed to be stocked into Washington waters. You can obtain more information about grass carp at this web site: http://www.ecy.wa.gov/programs/wq/plants/management/aqua024.html.

Waterbodies suitable for grass carp stocking:
Grass carp are generally not recommended for milfoil control because milfoil is not a highly preferred food. Some research has indicated that grass carp have food preferences and will consume more palatable plant species, such as pondweeds and waterweed, before they will eat milfoil. As a result, the concern is that they can enhance milfoil growth by removing competition from native plants and opening up more area for milfoil to colonize. Grass carp can be used for milfoil eradiation/control only in waterbodies where the eradication of ALL submersed aquatic plants can be tolerated. Sites where grass carp may be suitable for milfoil control are rare. They include very urban lakes like Green Lake in Seattle, privately-owned artificial lakes, or small lakes with a virtual monoculture of milfoil.

Special considerations:
WDFW requires that all inlets and outlets to the lake be screened to keep grass carp from leaving the system. Therefore, grass carp are generally not allowed in waterbodies with salmon or steelhead since these fish need to pass freely between the lake and salt water. WDFW requires a lake-wide plan before allowing grass carp to be stocked into public lakes.

Description of a grass carp stocking project:
The Department of Fish and Wildlife determines the applicability of stocking grass carp into a waterbody and provides a grass carp stocking rate. To achieve milfoil eradication, a high stocking rate of fish per vegetated acre must be used. Since milfoil is not a preferred food, grass carp will eat the more palatable plants first. If too low a stocking rate is used, grass carp may actually enhance milfoil growth by removing competition from native plants and opening up more area for milfoil to colonize. In the few Washington lakes where grass carp have eradicated milfoil, all the other submersed plants in the lake have also been eliminated (e.g.Silver Lake, Cowlitz County; Surfside Lakes, Pacific County). In Washington, grass carp do not appear to eat floating leaved plants like water lilies or emergent vegetation such as cattails and bulrush.

Once grass carp stocking has been approved, Fish and Wildlife will issue a permit and provide a list of fish farmers to the project sponsor. Most grass carp farms are located in the southern US because fish grow faster in warm southern waters. Also fertile fish are not allowed in Washington so they can't be raised here. The fish farmers generally sell ten to twelve inch fish. This size of fish is considered to be large enough to avoid bass predation. It is sometimes possible to purchase larger fish, but the costs per fish increase. Depending on the number of fish, grass carp are either transported to the site in special trucks or air freighted. One concern is that the fish farmers certify that the water that the grass carp are transported in is free from exotic organisms such as zebra mussels or the spiny water flea. The fish must also be certified as being triploid (sterile) and disease-free. The grass carp are released into the lake immediately upon their arrival. Most fish survive the trip from the fish farm, but some mortality from shipment stress is expected.

Many people prefer to stock their lakes in the spring to avoid winter stress. Once the fish are stocked, they are at risk from predation from birds of prey and otters. With abundant food and warm waters, the fish generally grow rapidly during their first summer and soon become too large for most birds to capture. Once the fish are stocked, observers may occasionally see them basking near the surface or moving in schools through the water. Their back fins often emerge from the water causing them to look like little sharks. If the correct numbers of fish have been stocked and mortality has been low, the amount of plants should slowly decline in the lake over two-three years with the palatable species disappearing before the milfoil plants. Once all submersed plants are eaten, grass carp have been known to consume detritus and organic material from the sediments (Gibbons, 1997).

As the stocked fish age, their feeding rate declines. Each year some mortality occurs and these sterile fish will eventually die out. As their population declines, native plants that have seeds or long-lived reproductive structures in the sediment may return. It is hoped that when this happens, milfoil will not reoccur in the waterbody.

General impacts of grass carp stocking:

There can be significant impacts to the waterbody following grass carp stocking. Since native plants provide habitat, sediment stabilization, and many other important functions, removal of all submersed plants can have a severe impact on the waterbody. Most of the impacts due to grass carp stocking are attributed to the removal of the plants rather than direct impacts of the fish.

The Department of Fish and Wildlife investigated the effects of grass carp on the water quality of 98 Washington lakes and ponds (Bonar, et. al, 1996). The average turbidity of sites where all submersed aquatic plants were eradicated was higher (11 nephelometric turbidity units [NTU's]) than sites where aquatic plants were controlled to intermediate levels (4 NTU's) or at sites where the vegetation was not affected by grass carp grazing (5 NTU's. In Silver Lake, NTU's of 50 were observed after all submersed plants were removed (Gibbons, 1997). Although there have been some reports that grass carp stocking can increase algal blooms, this does not appear to be the case in Washington. The increase in turbidity was all abiotic (probably suspended sediments). In other words, once the submersed species are removed or partially removed the lake becomes more turbid or muddy. Never the less, the satisfaction rate of the pond owners or lake residents with the results from stocking grass carp was high.

Frodge et. al (1995) observed positive water quality changes in Bull Lake, Washington and Keevies Lake, Washington after they were stocked with grass carp . Grass carp stocking and the resultant plant removal reduced some of the deleterious problems caused by excessive plant growth, such as low dissolved oxygen and high pH. The lake bottom in Silver Lake went from being anoxic and devoid of bottom dwelling invertebrates to oxidized and supportive of benthic organisms after grass carp had removed all submersed vegetation (Gibbons, 1997).

Pauley et. al (1995) studied fish communities for a six year period in three lakes before and after grass carp stocking. They concluded that while changes in fish populations did occur in the lakes, no consistent trend occurred after the introduction of grass carp. It should be noted that in two of the lakes, aquatic plants were not totally eliminated.

Waterfowl that feed on submersed plants are affected when these plants disappear. A report from Silver Lake (Gibbons, 1997) showed that although there were no clear indications that the number of waterfowl in the lake had declined after grass carp introduction in May 1992, there was a sharp decrease in American coots in 1994, 1995, and 1996. These data suggest that the loss of submersed plants from the lake resulted in fewer birds that depended on these plants for food from Silver Lake.

Follow-up:
Lake groups are strongly advised to monitor plant species and area of coverage, before and for several years after stocking grass carp. If the plants have not reduced in area or biomass after three years, more grass carp should be added. Since Fish and Wildlife issues the permit for extra fish, having monitoring data will provide them with the information to evaluate the request for extra fish.

References:
Bonar, S.A., Bolding, B., and Divens, M. 1996. *Management of aquatic plants in Washington State using grass carp: effects on aquatic plants, water quality, and public satisfaction* 1990-1995. Washington Department of Fish and Wildlife Research Report No. 1F96-05.

Frodge, J. D., Thomas, G.L., and Pauley, G. B. 1995. Chapter 6 - *Water quality effects of stocking sterile triploid grass carp in Keevies Lake and Bull Lake*. In: The Biology Management and Stocking Rates of Triploid Grass Carp *Ctenophyaryngodon idella*, and Their Effects on the Plant Community, Fish Assemblage, and Water Quality of Several Pacific Northwest Lakes. Final Report to the Washington Department of Ecology.

Gibbons, H.L. 1997. Silver Lake Phase II Study, 1996 Annual Report prepared for Cowlitz County by KCM, Inc.

Pauley, G.B., Marino, D.A., Thiesfeld, S.L., Vecht, S.A., Thomas, G.L., Beauchamp, D.A., and Bonar, S.A. 1995. Chapter 9 - *Impacts of triploid grass carp grazing on the game fish assemblages of Pacific Northwest Lakes*. In: The Biology Management and Stocking Rates of Triploid Grass Carp *Ctenophyaryngodon idella*, and Their Effects on the Plant Community, Fish Assemblage, and Water Quality of Several Pacific Northwest Lakes. Final Report to the Washington Department of Ecology.

CHEMICAL CONTROL STRATEGIES......................................

WHOLE LAKE FLURIDONE TREATMENT

Fluridone is a systemic herbicide that kills the entire plant and is generally non-selective since most submersed plants will be killed or affected by a whole lake treatment. Fluridone inhibits the formation of carotene (pigment) in growing plants. In the absence of carotene, chlorophyll is degraded by sunlight. Because this is a slow process and the plants can "grow out" of this if fluridone is removed, the contact time between the plant and chemical needs to be maintained for many weeks. Sonar® and Avast!® are the trade names for aquatic herbicides that contain fluridone as the active ingredient. The liquid formulation of fluridone has been used for whole-lake milfoil eradication projects. A granular formulation is also available, but has not been used for whole lake treatments. The premise for using fluridone as an eradication tool is that milfoil rarely produces viable seeds, so killing the vegetative growth will prevent spreading through fragmentation. Milfoil is particularly susceptible to fluridone and it is theoretically possible to achieve 100 percent kill. If <u>all</u> the milfoil plants are killed by fluridone treatment the only way that milfoil can reinfest the lake is to be reintroduced or germinate from seeds. Germination by seeds is considered rare.

Waterbodies suitable for whole-lake fluridone treatment:
Lakes and ponds suitable for whole-lake fluridone treatment are heavily infested with Eurasian watermilfoil throughout the littoral zone. Fluridone is not suitable for spot treatments (sites less than five-acres within a larger waterbody) since it is difficult to maintain enough contact time between the plant and the herbicide to kill the plant. If milfoil is limited to patches within the littoral zone, 2,4-D may be a more effective treatment method (see the 2,4-D milfoil eradication strategy). Due to the high treatment costs, fluridone treatments have been limited to smaller sites in Washington. The largest lake in Washington where this method has been used for milfoil eradication has been Long Lake (about 330 acres). In larger lakes, treatment of selected coves or embayments is possible, although milfoil will eventually reinvade from untreated areas.

Special considerations:
While there are no swimming, fishing, or drinking water restrictions when fluridone is in the water, the label warns against using the water for irrigation for seven to thirty days after treatment. Even at the low fluridone concentrations used to treat milfoil, some terrestrial plants may be sensitive to fluridone if they are watered with treated lake water.

Washington has had excellent success using this fluridone for milfoil eradication/control, but there is no guarantee that every lake group who tries this method will achieve the same results. Each site is different and many environmental factors may affect the treatment. Developing a site-specific plan for each lake is crucial to identifying environmental factors or concerns that may impact the treatment outcome.

Description of a milfoil eradication project using fluridone:
When the project goal is eradication, a whole lake fluridone concentration of 12-15 ppb (parts per billion or mg/liter) should be maintained in the lake for approximately ten weeks during the spring and/or summer. While it is possible to achieve successful milfoil control at lower concentrations (as low as 3-6 ppb), these higher levels are recommended to ensure that all milfoil plants are killed.

Before application, the lake volume must be determined to ensure fluridone is applied in a sufficient amount to result in the target whole lake concentration. If the lake is shallow and not thermally stratified, concentrations throughout the water column must remain in the 12-15 ppb range. If the lake is deep and thermally stratified (warm above and cold below), these concentrations can be maintained in the epilimnion (warmer surface layer of water) rather than throughout the water column.

Treatment costs will vary based on lake surface area, water volume treated, and the number of treatments needed to maintain the target concentration for ten weeks. The SePRO Company (distributor for Sonar®) has developed a new patented test called planTEST™ that their preferred applicators may use. Treated plants are collected a few weeks prior to treatment and planTEST™ determines the concentration of Sonar® needed to kill the target weed. If milfoil in the lake is particularly susceptible to fluridone, it may be possible to reduce the concentration of fluridone needed to effectively treat the infestation.

Treatments can start as soon as milfoil begins rapidly growing. This can be as early as April or May and as late as early July and is site-specific. Much depends on the timing windows for salmon usage (provided by Washington Department of Fish and Wildlife for each waterbody) since juvenile salmonids should not be exposed to chemicals. Another critical factor particularly in western Washington is water flow. A heavy rainfall may wash the herbicide out of the system. For deeper lakes, treatment should be delayed until the thermocline develops and stabilizes in summer. For these reasons, fluridone treatments in Washington often begin in June or July rather than earlier.

Fluridone is applied in a liquid formulation by sub-surface injection from trailing hoses by a state-licensed applicator. About a day or two after treatment, water samples should be collected to determine fluridone concentrations. The number of samples required depends upon the size and shape of the lake. In a long narrow lake, three samples may be enough to determine lake concentration. In a small round lake, one sample taken in the middle may be sufficient. In a lake with many coves or channels, a number of samples may be needed to determine a whole lake concentration. Testing the water ensures that the target concentration of fluridone has been met. The SePRO Company and Griffin LLC (distributor for Avast!) both have fluridone analysis test kits. Test results can be available within 48 hours and each sample costs about $100. Other laboratories can also perform fluridone analysis, but turn around times for results may be longer. Fluridone concentrations are maintained in the lake over time by the application of additional herbicide at about bi-weekly intervals or as needed. To determine how much herbicide to add, water samples are collected about 10 to 14 days after the initial treatment and analyzed for fluridone. Generally during this two-week period, fluridone concentrations decrease by about half, due to plant uptake and exposure to sunlight. Fluridone is also more persistent in cooler waters. After fluridone concentrations are determined, the applicator applies enough herbicide to the lake to bring the whole lake concentration back up to the 12-15 ppb range. This scenario continues until fluridone concentrations have been held at 12-15 ppb in the lake for ten weeks. This fluridone concentration and exposure time should be sufficient to kill milfoil plants. During a typical treatment, the applicator may apply fluridone to the lake four times.

The SePRO Company has also developed a new patented test called effecTEST™ that their preferred applicators may use. Treated plants are collected at about five to six weeks after the initial treatment and effecTEST™ determines whether these plants have received enough herbicide to kill them or if a higher (or lower) concentration is needed.

General impacts of fluridone treatment:
There are significant impacts to the waterbody during and following treatment. Fluridone is a generally non-selective herbicide, which means most submersed plants and some floating leaved plants will be killed by fluridone during the treatment. Emergent species like cattails will be impacted but will recover. A week to three weeks after the initial treatment, observers will see the growing tips of aquatic plants bleach pink to white. Water lilies will appear bleached and cattails and other emergent species may look variegated. Since this is a slow process, low oxygen conditions do not develop. The plants eventually drop out of the water column by about six weeks post-treatment.

While there is no direct toxicity of fluridone to animals, the loss of habitat does cause indirect impacts. The smaller fish lose their hiding places and because the larger fish can find them easily, they have greater chances of being eaten. Waterfowl that eat vegetation tend to move onto other vegetated waterbodies while waterfowl that eat fish enjoy better fishing opportunities on the treated lake. Sometimes increased algal blooms are observed in the year of treatment and for a year following treatment. However, eventually the lake reaches a new equilibrium and native aquatic plants recover. Naturally occurring plants have viable seeds, tubers, and overwintering buds that allow them to revegetate the lake the year following treatment, while milfoil does not. In Washington the colonization of the lake bottom by plant-like algae called brittlewort (*Nitella* spp.) and stonewort (*Chara* spp.) is often observed following a fluridone treatment. This is because algal species are resistant to fluridone and removing milfoil opens up space for them to colonize.

Up to 100 percent of the Eurasian watermilfoil in the lake should be killed. However in inlets or areas where the herbicide may be diluted by flowing water (including in-lake springs), milfoil may be undertreated and must be physically removed if eradication is to be successful. These areas should have been identified during plan development and alternative methods planned for milfoil removal. Undertreatment or no treatment of milfoil in inlet areas may result in the lake being reinfested unless immediate management methods are undertaken.

Follow-up:
For lakes that are heavily infested with milfoil, the goal of eradication should only be sought when lake residents are willing to finance and conduct the follow-up monitoring and treatments that are essential to ensure long term success. The littoral zone of the lake should be thoroughly inspected by divers in the fall of the treatment year and the next spring as well to identify any milfoil plants that may have been undertreated. Areas where this might happen include areas of lake bottom with springs or near inlet streams. Any remaining milfoil plants should be hand

pulled or covered with bottom barriers (See: Eradication - Hand Pulling and Bottom Barrier Installation). Diver and surface inspections should continue at least twice a year during the growing season on an ongoing basis. Survey work should be as frequent as can be afforded, since small milfoil plants may be easily overlooked. Often divers report finding two to three foot tall milfoil plants in areas that they had extensively searched only three weeks earlier. As native plants recover, it will become more difficult to locate any milfoil plants.

Very important note!
In most Washington lakes treated with fluridone, milfoil is found growing in the lake from two to five years later. It is suspected that milfoil is reintroduced via boating activity, since it is often discovered near a public boat launch. As long as the lake group has continued the survey work, these new introductions can be identified quickly and targeted for removal before milfoil reestablishes. In treated lakes where lake groups have continued the diver and surface inspections, milfoil remains at extremely low levels and recreation, fishing, and habitat remain healthy. In the few lakes where inspections did not continue, milfoil reinvaded and the lakes returned to pre-treatment infestation levels. It is interesting to note that the one lake where milfoil never returned after treatment is a canoe and kayak lake only and located on an island (Goss Lake).

Follow-up is the key!
While it is very difficult to totally eradicate milfoil from a lake forever, extensive and long-term follow-up activities make it possible to maintain extremely low levels of milfoil that will not impede recreational activities or impact native plant communities. As an example, Long Lake in Thurston County was treated with fluridone in 1991. In 1995, milfoil was discovered growing near the public boat launch. Since then the lake residents and Thurston County have been successfully maintaining extremely low levels of milfoil in the lake by surface and diver survey and hand pulling. In 2001 about 90 pounds total wet weight of milfoil was removed from the 330-acre lake (Ryan Langen, personal communication). Much less milfoil was found in 2002. These activities are not inexpensive, but are considered a necessary cost to maintain this lake in good condition for recreation and habitat. Should these management measures cease, milfoil would probably reinfest the lake within three to five years.

2,4-D TREATMENT

2,4-D is a relatively fast-acting herbicide that kills the entire plant (systemic herbicide). Its mode of action is primarily as a stimulant of plant stem elongation. This herbicide is considered to be "selective" for milfoil because it generally targets the broad-leaved plants (dicots) like milfoil. Most other aquatic plants are monocots (grass-like) and are unaffected by 2,4-D. Navigate® and Aqua-Kleen® are granular 2,4-D products registered for aquatic use and DMA*4VM® is a liquid formulation.

Waterbodies suitable for 2,4-D treatment:
Sites suitable for treatment include lakes or ponds partially infested with Eurasian watermilfoil such as waterbodies where milfoil has recently invaded, but where the extent of the infestation is beyond what can be removed by hand pulling or bottom screening. In these situations an herbicide, like 2,4-D, that is effective for spot treatment can be used to reduce the amount of

milfoil so that hand pulling can remove any milfoil plants that are not killed. 2,4-D is suitable for spot treatment because it is a fast-acting herbicide that only needs a 48-hour contact time with the plant. 2,4-D can be used for milfoil control in heavily infested lakes, but it does not provide the nearly 100 percent kill of the herbicide fluridone. Because many plants remain alive and scattered throughout the littoral zone after 2,4-D treatment, hand pulling extensive areas after treatment may not be effective in heavily infested lakes. Lake residents must be willing to fund the follow-up activities necessary to ensure continued milfoil eradication (or maintenance at extremely low amounts).

Special considerations:
Water users need to be identified prior to 2,4-D application. Water within the treatment areas cannot be used for drinking until 2,4-D concentrations have declined to 70 ppb and water used for irrigation cannot be used until 2,4-D concentrations are 100 ppb or less. If water users do not have other water sources, the project proponents must arrange for alternative water supply during the time that 2,4-D is in the water. In Washington, testing has shown that water both inside and outside of the treated area is generally below the drinking water standard three to five days after treatment.

Description of a milfoil eradication project in Washington using 2,4-D:
Lakes where 2,4-D is being used for milfoil eradication in Washington typically have milfoil scattered in patches within the littoral zone. The lake is surveyed immediately prior to herbicide application and milfoil locations are mapped and Global Positioning System (GPS) points established.

Herbicide application can begin as soon as milfoil starts rapidly growing. Effective treatments can be made as early as April or May and as late as early September. Timing is also dependent on salmon usage since juvenile salmonids should not be exposed to chemicals. Treatment in the spring/summer should be followed by a late summer survey and possible retreatment if large patches remain or if more milfoil is discovered in untreated areas of the lake.

A month after the initial 2,4-D treatment, the littoral zone of the lake should be thoroughly inspected by divers to identify and map remaining milfoil plants. Sparse populations of remaining milfoil plants should be hand pulled or covered with bottom barrier. Larger, denser patches may need to be treated again with 2,4-D, although in that case some assessment should be made as to why the initial treatment was ineffective. Diver and surface inspections should continue at least twice a year during the growing season. Survey work should be as frequent as can be afforded since small milfoil plants may be easily overlooked within the native plant beds. Often divers report finding two to three foot tall milfoil plants in areas that they had extensively searched only three weeks earlier.

The herbicide is available in a granular and liquid form and application must be made by a state-licensed applicator. The granular formulation of 2,4-D is typically applied using a bow-mounted centrifugal or blower-type spreader and uniformly spread over the water above the milfoil beds and slightly beyond. The clay particles sink to the bottom or are caught up in the plants. The herbicide slowly releases from the clay over the next day. Granular formulations are generally recommended for spot treatment since liquid applications may have more tendency to drift away from the milfoil beds. When the liquid formulation is used, it is applied using subsurface trailing hoses. In both cases, if the project is funded by an Ecology grant or if there are irrigation or drinking water concerns, monitoring will be required. A 2,4-D analysis test kit should be available soon or environmental laboratories can also perform 2,4-D analysis. Rapid turn around of results costs more.

General impacts of 2,4-D treatment:
2,4-D is a selective herbicide and milfoil is particularly susceptible at a labeled rate of about 100 pounds per acre (granular product). At this rate impacts to other aquatic plant species are minimal. Even if applied at higher rates there are only a few other aquatic plant species that are affected by 2,4-D. A study conducted in Loon Lake Washington showed that Eurasian watermilfoil was the only aquatic plant whose growth was statistically reduced by the 2,4-D application (Parsons, et. al, 2001). In the Loon Lake study up to 98 percent of the Eurasian watermilfoil biomass in the treatment plots was removed after the July treatment. Environmental and human health impacts of 2,4-D are addressed in Ecology's risk assessment of 2,4-D at the following web address: http://www.ecy.wa.gov/biblio/0010043.html.

A few days after the 2,4-D treatment, observers will see the growing tips of milfoil plants twist and look abnormal. These plants will sink to the sediments usually within one to two weeks of treatment. Unless treatment takes place in dense beds of milfoil, it is unlikely for low oxygen conditions to develop. Results of spot treatment may be variable depending on water movement, size of treatment plot, density of milfoil, weather conditions, underwater springs, etc.

Follow-up:
Follow-up is essential to ensure the success of eradication. Used alone, 2,4-D is not an eradication tool. Some plants survive the treatment and regrow, so these plants must be removed by other means. Surveys done in Minnesota indicated that, 2,4-D use did not result in eradication of milfoil over the long-term (Crowell, 1999). Treated lakes for which there was no follow up survey work or treatment eventually ended up with milfoil throughout the littoral zone.

Follow-up is the key!
Once milfoil is discovered in a lake, it generally requires continual maintenance to keep it at low levels. Even if milfoil appears to have been eradicated it often is reintroduced by boaters. As long as the lake group continues surveying on a yearly basis, new introductions can be identified quickly and targeted for removal before milfoil can re-establish in the lake. In treated lakes where the lake group has continued diver and surface inspections, milfoil remains at extremely low levels, without impacts to habitat or recreational activities.

References:
Crowell, W.J. 1999. *Minnesota DNR tests the use of 2,4-D in managing Eurasian watermilfoil*. Aquatic Nuisance Species Digest. 3(4):42-46.

Parsons, Jenifer K.; K.S. Hamel, J.D. Madsen and K.D. Getsinger. 2001. *The Use of 2,4-D for Selective Control of An Early Infestation of Eurasian Watermilfoil in Loon Lake, Washington*. J. Aquat. Plant Manage. 39:117-125.

LITTORAL ZONE ENDOTHALL TREATMENT

Endothall (active ingredient) is a fast-acting contact herbicide (an herbicide that burns back the above-sediment vegetation, but doesn't kill the roots) that is believed to disrupt the plant biochemical processes at the cellular level. The dipotassium salt of endothall is used for aquatic plant control and is formulated as Aquathol® K (liquid) and Aquathol® Super K Granular. The Washington State Department of Ecology recently completed a risk assessment and an environmental impact statement for endothall. The risk assessment and the impact statement can be viewed at the following web address:
http://www.ecy.wa.gov/programs/wq/pesticides/seis/risk_assess.html.

Endothall has been used for years in Washington lakes to spot treat milfoil along shorelines because it is rapidly-acting, and when used at higher concentrations (2-3 parts per million (ppm) needs only a short contact time to remove milfoil vegetation. Recently, lower concentrations (1-1.5 ppm) of endothall have been used to treat milfoil in whole lake or littoral zone treatments. Milfoil can be controlled (vegetative growth removed) at 1 mg/l active ingredient endothall with an exposure time of 48 to 72 hours. At this concentration, endothall impacts some native plant species to a lesser degree (Skogerboe and Getsinger, 2001).

The benefit of using low levels of endothall is to remove exotic weeds like milfoil, while allowing native species to recover. While this is not an eradication technique, it may be useful for maintaining more acceptable levels of milfoil in a lake by periodically treating the littoral zone with low concentrations of endothall. It is possible that treatments can occur as infrequently as every three years. Ecology, along with the Department of Fish and Wildlife, and the endothall manufacturer, Cerexagri, is conducting a study on a small western Washington lake (Kress Lake) to determine the efficacy of using low levels of endothall to control milfoil.

Waterbodies suitable for endothall treatment:
Whole littoral zone treatment with endothall cannot be considered as an eradication method. Endothall will suppress the growth of milfoil and may allow native plants to recover and therefore increase species diversity within a lake. Lakes and ponds considered suitable for littoral zone treatment are heavily infested with Eurasian watermilfoil. This method may be used where it is considered too expensive, or the waterbody is too large to use milfoil eradication strategies.

Special considerations:
The endothall label has a three-day fish consumption restriction in the area of treatment and an irrigation and stock watering restriction for 14-days after treatment. Ecology advises waiting 24 hours after any herbicide treatment before swimming, although there is no official label restriction for swimming. Care must be taken with the application so that low oxygen conditions do not develop as plants decompose.

Any whole lake or widespread herbicide treatment, such as littoral zone endothall treatment should be conducted under an integrated aquatic vegetation management plan.

Description of the Kress Lake project, using endothall:

A detailed report about the treatment and sampling methodology and the results of the Kress Lake project can be seen in Ecology's Aquatic Plants Technical Assistance Program: 2001 Activity Report at the following web location: http://www.ecy.wa.gov/biblio/0203025.html. The information/data below were taken from that report. The project is still ongoing and additional data will be collected in August 2002 and June 2003.

Kress Lake

Kress Lake, a 30-acre manmade lake in Cowlitz County, is a popular fishing lake with a nuisance population of milfoil. Kress Lake is owned and managed by Washington Department of Fish and Wildlife as a warm water fishery (bass, channel catfish, and sunfish) and has no inlet or outlet. Trout and surplus steelhead are also stocked into this landlocked lake. Prior to treatment, aquatic plants were found growing throughout the lake with milfoil as the dominant species. Both fishing and the fishery of the lake were being negatively impacted by the milfoil plants (Stacey Kelsey of Fish and Wildlife, personal communication). She reported that excessive vegetation was contributing to a stunted fish population, and milfoil mats, especially along the shoreline, were interfering with fishing. The endothall study was undertaken to see if a low concentration of endothall could selectively remove milfoil, increase species diversity, and improve fishing and the fishery.

On June 21, 2000, a state-licensed applicator applied Aquathol® K at rate of 1.5 ppm to ten acres around the edge of the lake. A second treatment took place a month later with an additional 10 acres treated from the shorelines toward the center of the lake using the same application rates.

Assessment of the treatment project is ongoing. Three months after treatment the endothall treatment reduced the frequency with which the vascular plants (flowering plants like milfoil) were found, while not affecting the macroalgae muskgrass (*Chara* sp.). During this period, vascular plants were reduced to the point of eliminating plant cover completely in locations throughout the lake. By one year after treatment and throughout that summer (June 2001 and September 2001) the frequency of muskgrass appeared to level-off while some of the vascular plants increased (e.g. waterweed, (*Elodea candensis*), milfoil (*M. spicatum*), and bladderwort (*Utricularia* sp.). This recovery appeared to fill in areas left bare of plants the previous summer. The pondweeds (*Potamogeton* sp.) did not appear to be rebounding.

Two species showed a significant change in their biomass before and after treatment. The biomass of waterweed (native plant species) increased significantly one year after treatment.

About one third less milfoil biomass was collected after treatment (76 g/m^2 - before treatment versus 23 g/m^2 - one year after treatment).

The species list from each sample date shows that the species diversity was greatest in June 2001; one year after treatment. A total of 12 different plant types were present at that time. This is almost double the number found before the herbicide treatment. The number of plant types observed decreased to 9 by the September 2001 sampling event. This may have been due to sampling variability, increased dominance by a few species making locating less common species more difficult, or the seasonal die off of selected species.

Endothall (Aquathol K®) significantly reduced both the biomass and frequency of observation of milfoil, over the study period. However, by 1.3 years after treatment milfoil was showing a significant increase in frequency, so the duration of the control may be ending. The results also show an increase in overall submersed aquatic plant species diversity one year after treatment.

Although the June 2002 data have not been statistically analyzed, surprisingly milfoil did not appear to have increased in frequency or biomass when compared to the previous year (Kathy Hamel, personal observation).

General impacts of endothall treatment:

Generally endothall is used to spot treat areas and therefore impacts are not widespread. Using low levels over the lake littoral zone does cause adverse impacts in the short term, since many vascular plants are affected by the treatment. Within a few weeks of treatment, most plants in the treated area are brown and dropping from the water column. In Kress Lake, an algal bloom was observed a few weeks after the herbicide treatment. This may have been caused by the nutrients released from the decaying plants. (Note: an algal bloom was also observed in August 2002, although no herbicide treatment had taken place for two years. Many lakes are naturally nutrient-enriched.) Sampling ten weeks after treatment showed mostly dead and decaying plants lying along the bottom and bright green healthy muskgrass populations. A year after treatment, the native plant community was recovering, but milfoil, though present, did not dominate the plant population.

Fish and Wildlife staff have been pleased with the results, indicating that anglers are now able to fish without tangling their gear in milfoil.

Follow-up:

This is potentially a new method available for the control of milfoil in heavily infested lakes. The results from Kress Lake have been excellent. The lake was treated in 2000 and no further treatment was needed in 2001 or 2002. At this stage of assessment, we do not know how often the lake will need to be treated to continue the suppression of milfoil.

References:

Parsons, J., B. Dickes, and A. Fullerton, 2001. Aquatic Plants Technical Assistance Program: 2001 Activity Report. Washington Department of Ecology

Skogerboe, J.G. and K.D. Getsinger. 2001. *Endothall species selectivity evaluation: southern latitude aquatic plant community*. J. Aquat. Plant Manage. 39:129-135